Scaling Exponent of Multiplicity Fluctuations in Ginzburg-Landau Phase Transition in 14.5A GeV/c ^{28}Si-AgBr Interactions

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Introduction

The studies relating to intermittency in hadronic and nuclear collisions at high energies have opened up a new and fruitful field of research; studies of non-statistical fluctuations in such collisions have provided some interesting insights into various physical phenomena. Intermittency, defined as an increase of normalized factorial moments with increasing resolution phase space resolution, is seen in all types of collisions. Many attempts [1, 2] have been made to investigate the occurrence of intermittency in high energy nuclear collisions, but none could provide a satisfactory approach for studying non-statistical fluctuations in multiparticle production. In high energy nuclear interactions, study of non-statistical fluctuations entered into a new era when Bialas and Peschanski [1] proposed a methodology known as Scaled Factorial Moments to investigate non-statistical fluctuations in multiparticle production. Furthermore, study of dynamical fluctuations would help understand the physics involving QGP formation [3] in ultra-relativistic heavy-ion collisions.

Currently, one of the primary objectives for performing high energy heavy-ion experiments is to search for the possible signals of QGP formation. Another interesting aspect to be investigated is the order of such a phase transition from deconfined QGP to hadrons, if it occurs at all. Analysis based on intermittency can throw light on the formation of QGP and the order of phase transition. A simple model that can provide sufficient hint towards the nature of the second-order phase transition is two dimensional Ising model [4, 5].

Mathematical formalism

The Ginzburg-Landau (GL) model [6] has been extensively used to describe scaling of scaled factorial moments for both second order [7, 8] and first order [9, 10] phase transitions. Ochs and Wosiek [11] have pointed out that one dimensional scaled factorial moments follow a modified power-law of the type

$$\langle F_q(\delta\eta)\rangle \propto [g(\delta\eta)]^{\phi_q} \qquad (1)$$

where bin width $\delta\eta$ in the full range with a nonlinear function, or equivalently, pairs of moments are related [11] as:

$$\ln\langle F_q\rangle = \beta_q \ln\langle F_2\rangle + G_q \qquad (2)$$

Here $\beta_q = \phi_q/\phi_2$ and G_q are constants; ϕ_q represent the intermittency indices which always have positive values and ϕ_2 is intermittency index corresponding to second order of the moment. The slopes β_q can be obtained by plotting $\ln\langle F_q\rangle$ against $\ln\langle F_2\rangle$.

Hwa and Nazirov [7, 8] have pointed out that slopes β_q in Eq. (2) can be used to probe the nature of intermittent systems. They have discussed the intermittency phenomenon of hadrons arising from quark-gluon plasma in terms of Ginzburg-Landau description of second order phase transition and have obtained the following relationships:

$$\beta_q = (q-1)^{\nu} \text{ and } \nu = 1.304, \qquad (3)$$

where ν is scaling exponent which has a critical value of 1.304; ν being a universal quantity valid for all the systems describable by the GL theory. It is independent of the dimensions or the parameters of the model. The scaling exponent, ν, can be used to study phase transition directly by analyzing the data appropriately. If the value of scaling exponent obtained from the experimental data is less than the critical value, occurrence of a second order quark-hadron phase transition in the interactions is a possibility [7]. Value of ν higher than the critical value would imply absence of such a phase transition.

In this paper we report the results of an investigation regarding possibility of formation of QGP and the order of phase transition in 14.5A GeV/c ^{28}Si-AgBr interactions using scaled factorial moments in the frame work of GL formalism. The results of the study are also compared with the corresponding results obtained for the FRITIOF and HIJING generated data involving interactions with the same descriptions.

Results and discussion

A power-law behavior between <F_q> and <F_2> has been observed in the GL description of the scaled factorial moments, expressible by Eq. (2). Fig. 1 exhibits the variations of ln<F_q> with ln<F_2> for the experimental, FRITIOF and HIJING simulated data. A linear rise in ln<F_q>, when plotted against ln<F_2>, is discernible for all the data sets. It is seen from the figure that ln<F_q> are linearly related to ln<F_2>, which indicates a power-law behavior and confirms the validity of Eq. (2) for our data. Almost similar pattern has been observed for the simulated data. The solid

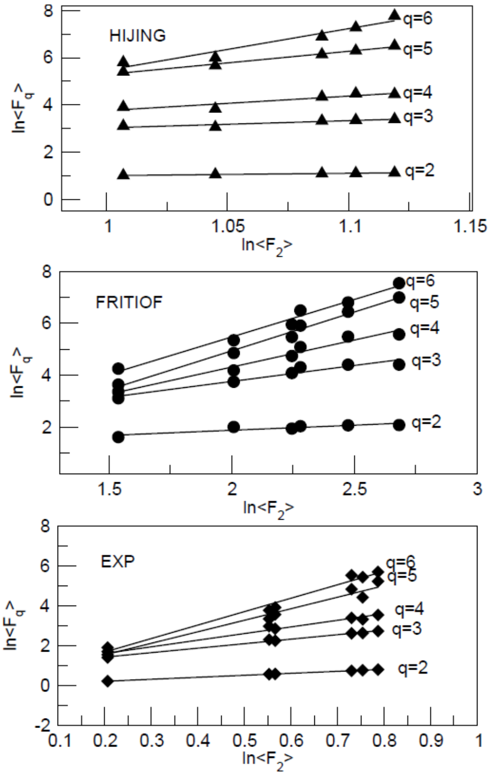

Fig. 1. **Variations of ln<F_q> with ln<F_2> for the experimental and simulated data on 14.5A GeV/c**

lines in the figure are obtained by the least squares fits to the data. Fig. 2 exhibits the variations of lnβ_q with ln(q-1) for the experimental and simulated data sets. Slopes β_q are obtained by the least squares fits to the data obtained from ln<F_q> vs ln<F_2> plots. The solid lines in the figure are the best linear fits to the experimental and simulated data. It is worth mentioning that the values of the critical exponents, ν obtained from Eq. (3) for both experimental and FRITIOF data are less than the critical value ν = 1.304, the values of ν obtained for the experimental, FRITIOF and HIJING simulated data are found to be 1.262±0.068, 1.245±0.071 and 1.866±0.094 respectively. Incidentally, the experimental value of the critical exponent ν for the ^{28}Si-AgBr interactions is quite close to the universal value of 1.304. However, a larger value of ν for the HIJING simulated data does not indicate significant fluctuation. Since β_q describe the

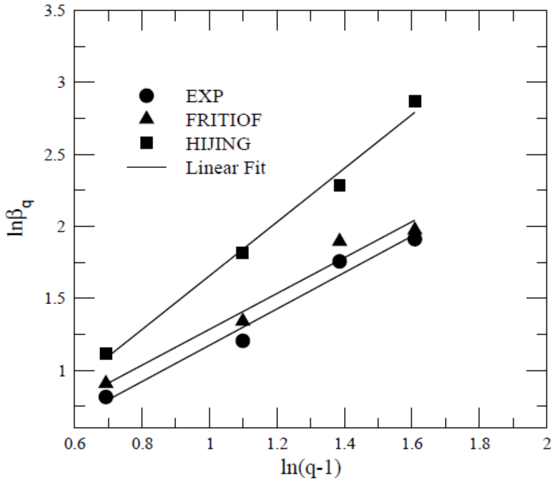

Fig. 2. **Variations of lnβ_q with ln(q-1). Data points are determined from Fig. 1**

scaling behavior of F_q relative to F_2, a larger ν may be a consequence of a smaller value of intermittency index, ϕ_2.

Conclusions

The generalized power-law behaviour between <F_q> and <F_2> is observed in GL description which supports occurrence of self-similar cascade mechanism in multiparticle production in hadronic and nuclear collisions. Incidentally, the value of critical exponent,ν, for the experimental and FRITIOF data are quite close to the critical value of 1.304. Thus there appears to be a possibility of the presence of second order phase transition in the interactions considered, which agrees reasonably well with the predictions of Ginzburg-Landau theory. However, the new frontier opened up by the high multiplicity events at LHC energies provides a fertile ground for investigating phase transition, which is not possible at lower energies.

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